Building the International Space Station

Presentation to AIAA Greater New Orleans Section

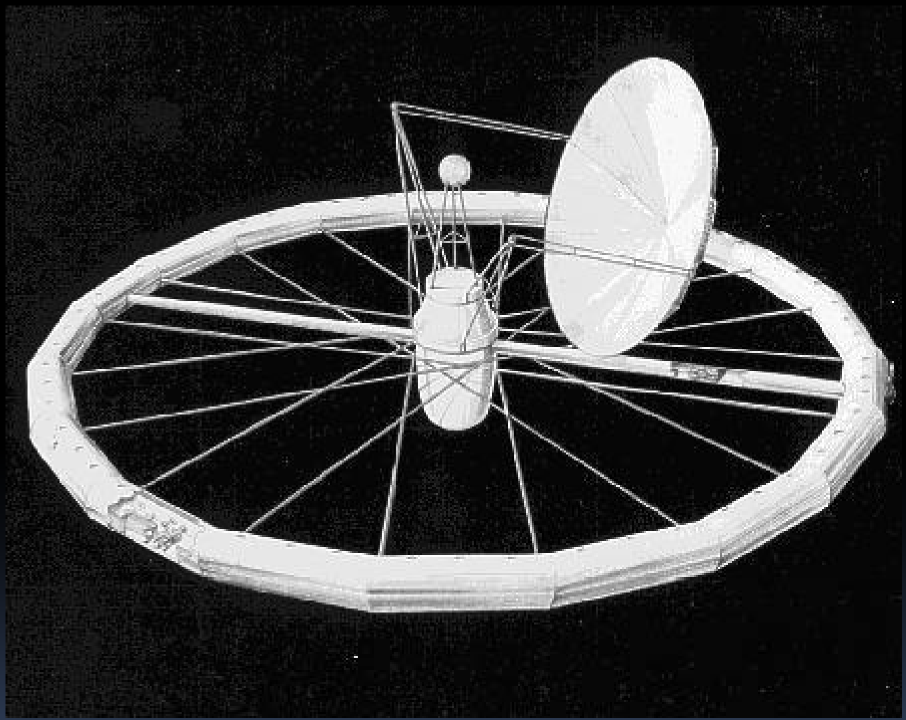


Randy Galloway
NASA Stennis Space Center
November 7, 2011
EB-2011-11-00033-SSC

The Dream

- Building a Space Station was an early goal of Space pioneers
  - Willy Ley articles of the 1940s- 1950s and ***2001: A Space Odyssey*** formed the popular idea of what one would be like
    - Large "wheel" type structures with artificial gravity at extremity, microgravity in the "hub"
      - This design has yet to be built

Von Braun Space Station Sketch (ca. 1947)



Early Models

- U.S.
  - Skylab
    - Launched 1973
    - 3 crewed missions 1973-74, 28-84 day missions
    - Abandoned and de-orbited (uncontrolled) in 1979
- U.S.S.R.
  - Salyut 1-7
    - 1971-1985
    - Evolutionary designs built by Russians for civilian and military use
  - Mir
    - 1986-2001
    - First true long duration space station and first with multiple international contributions

Skylab (1973)



Salyut 7 (1985)



Beginnings

- Following Skylab, U. S. focused on development of Space Shuttle as follow on to Apollo with goal of making access to space cheaper and more routine
- Soviet success on operations of Salyuts through the late 70's –early 80's had created a perception that the U.S. and its allies were behind
- Desire to bridge the gap, while building on Free World partnerships already started on the Space Shuttle program, led President Reagan to ask NASA to begin a Space Station project in his 1984 State of the Union address

Definition Phase

- NASA began Phase A studies in 1984
  - Eventually settled on large dual keel truss with multiple large modules in racetrack configuration with large photovoltaic arrays and solar dynamic turbines
    - International contributions included robotics from Canada, modules from Europe and Japan
  - Multiple foci—satellite servicing, earth science, space science, microgravity science, materials research, biomedical research….
  - Work divided among 5 NASA Centers
    - Marshall Space Flight Center (MSFC)
    - Johnson Space Center (JSC)
    - Goddard Space Flight Center (GSFC)
    - Lewis Research Center (LeRC) *(now Glenn)*
    - Kennedy Space Center (KSC)

“Power Tower”
1984



Dual Keel Design (1986)



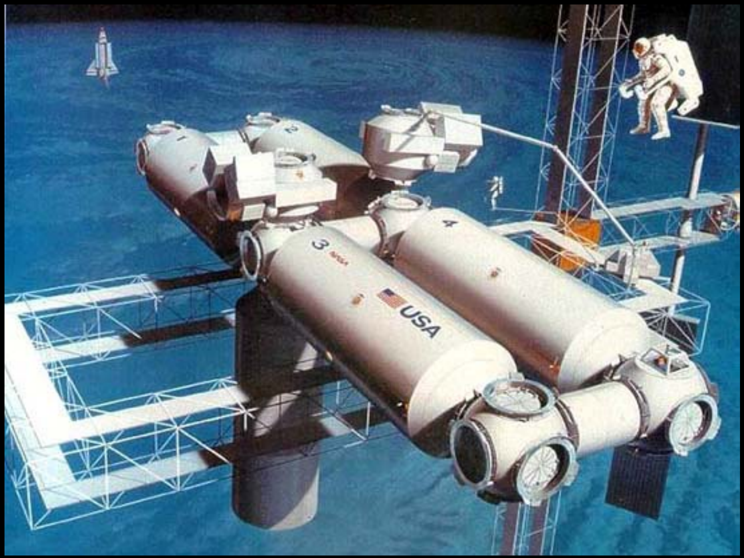
Development Starts

- In middle of Phase B studies, Space Shuttle *Challenger* accident occurred (January 1986)
  - Resulted in lowered flight rates and much lower payload capacity causing stretched out assembly sequence and more flights
  - NASA's overall credibility questioned seriously
- New management model proposed (Level II at Reston, VA)
- Phase C/D contract awards made to Boeing (MSFC), McDonnell Douglas (JSC), GE (GSFC), Rocketdyne (LeRC), Grumman (Level II Integration) in 1987-88

“Freedom” 1988-1993

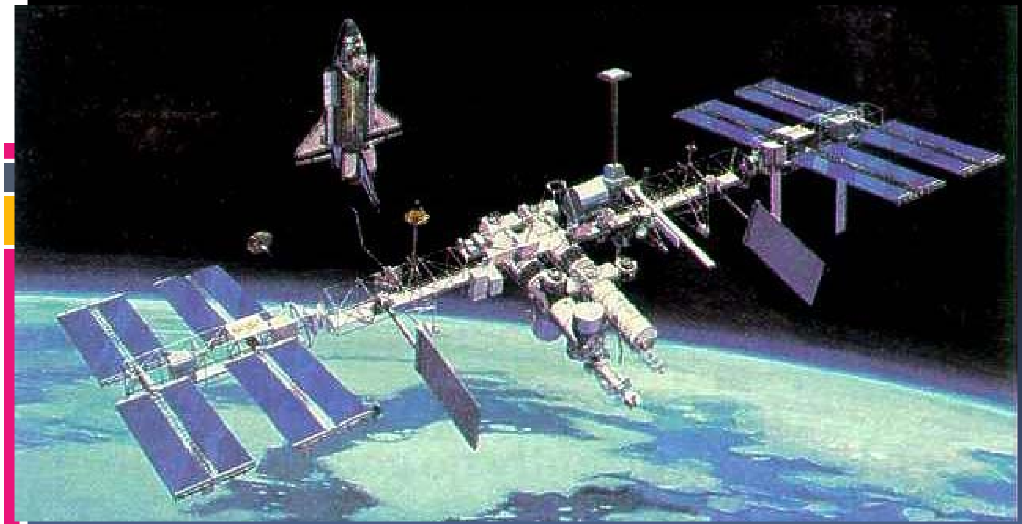
- Named Space Station “Freedom” by President Reagan in 1988
- Inter-governmental Agreement reached in 1988 that tied Canada, Japan, and Europe to the Program with contributions of modules and robotics
- The 1988-1993 period was marked by almost continual redesign and down-scoping for budgetary and technical reasons
  - Multiple changes to annual and run-out budgets
  - Weight / power requirements growth caused major scrubs and redesign of several elements
  - EVA projections for assembly and maintenance forced redesigns and drew major scrutiny from media and Congress

Faces of “Freedom”



1985

1987



1991



Winds of Change

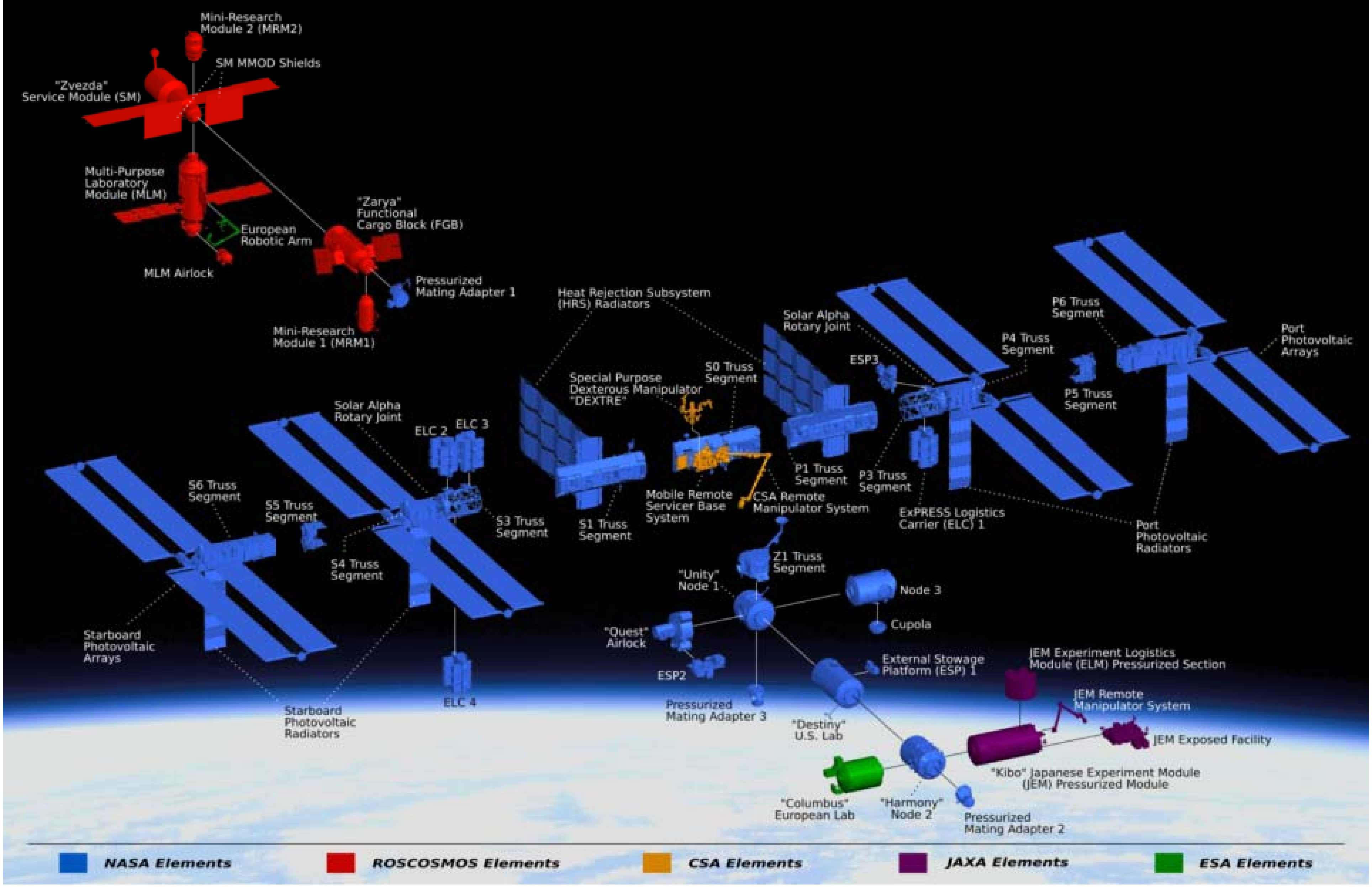
- Combination of budget and technical concerns, an Administration change, and fall of the Communist bloc drove case for consideration of major changes to the Program in 1993
  - Sweeping redesign resulted in further de-scoping of U.S. contributions and addition of Russian modules to the Station to provide early power, guidance/control, and crew accommodations
  - Also moved management of the program to JSC and established a “single Prime” contractor, Boeing
  - Re-designated as the “International Space Station” or ISS

International Space Station

Created by a partnership of 5 space agencies representing 15 countries

Over 10 years and 32 missions to assemble

A collaboration of 5 space agencies



Assembly Comparison



The Pyramids

Most of them took about 27 years to build



The Coliseum

It is one of the greatest works of Roman architecture and engineering. Took about 15 years to build

.



Taj Mahal

The plinth and tomb took roughly 12 years to complete. The remaining parts of the complex took an additional 10 years



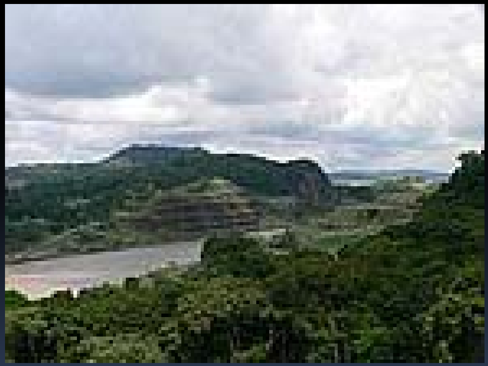
The Washington Monument

The actual construction of the monument began in 1848 but was not completed until 1884



Great Wall of China

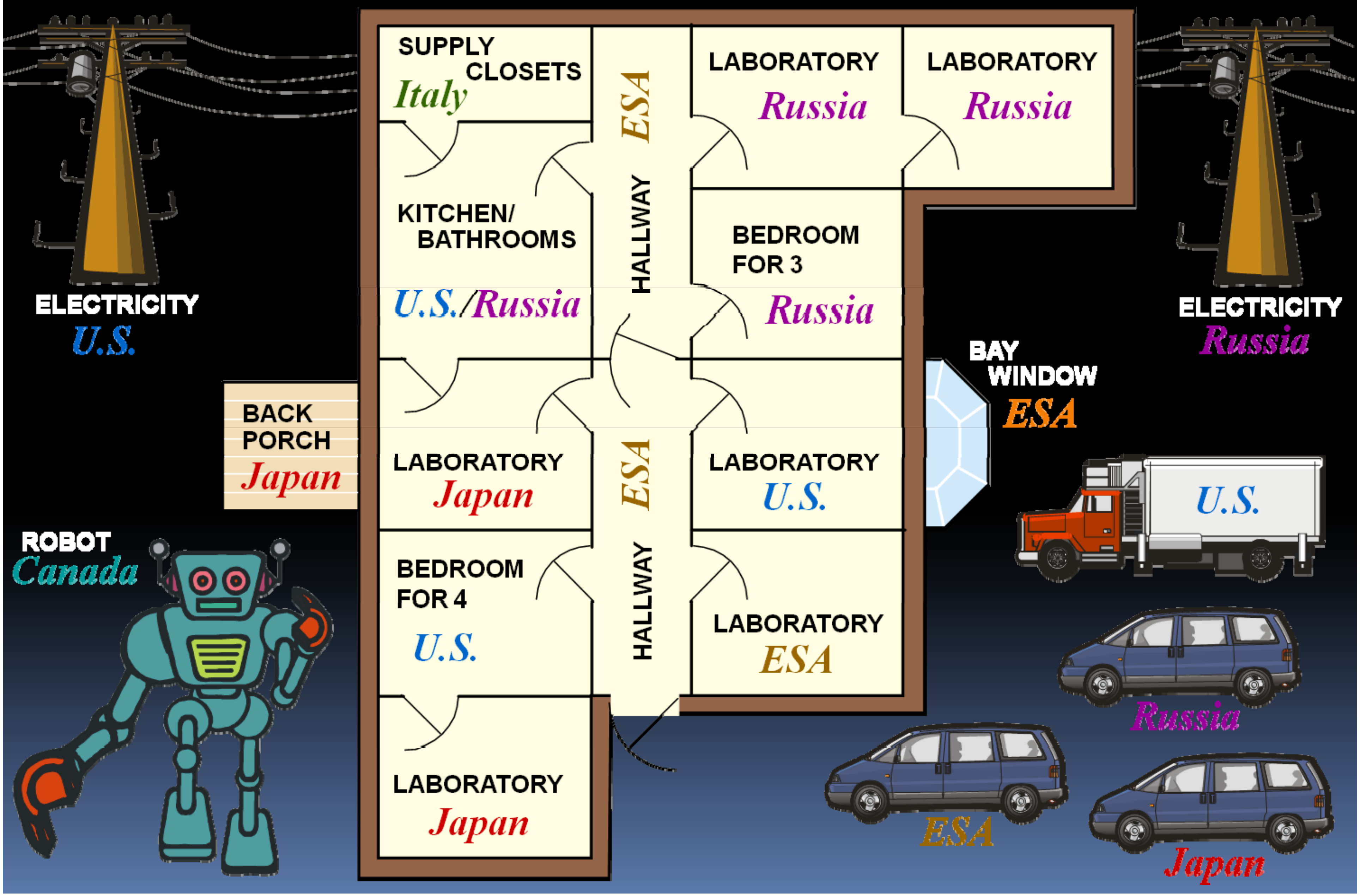
The wall was constructed sporadically, starting in 221 B.C. during the Chin Dynasty, and ending in the 1500's during the Ming Dynasty, over 1700 years!



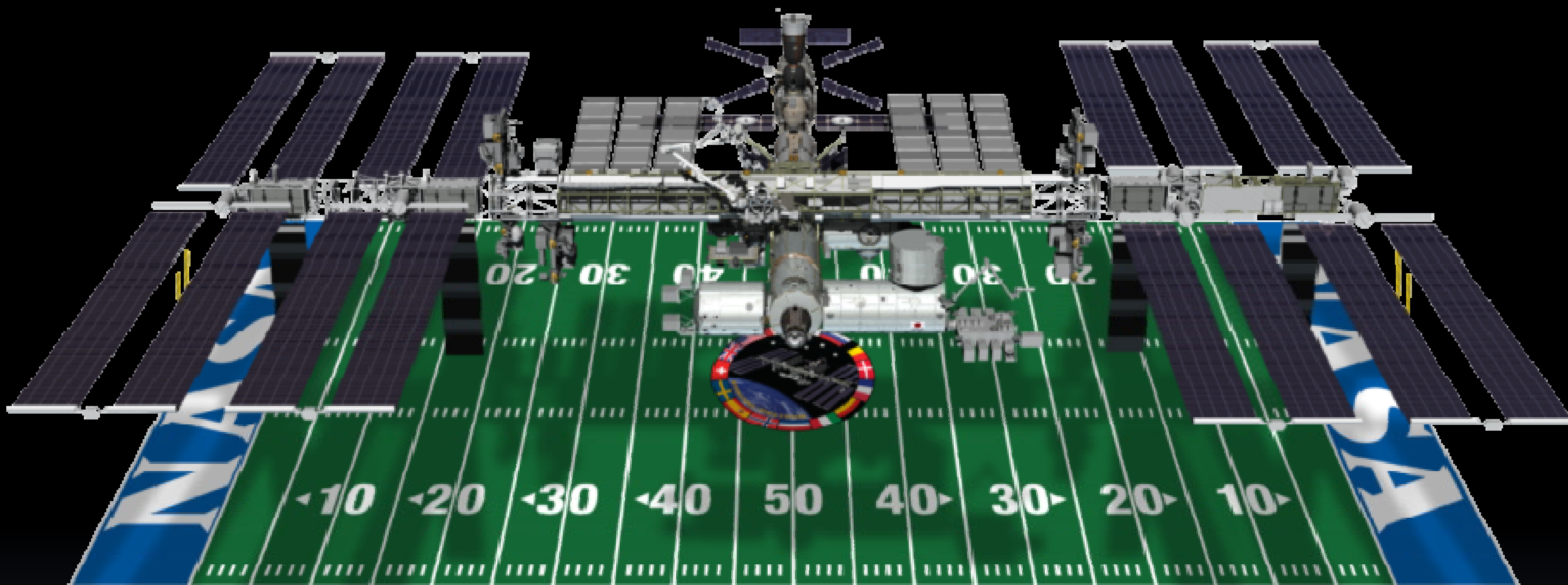
The Panama Canal

Although the concept the canal dates back to the early 16th century, the first attempt to construct a canal began in 1880. After this attempt failed, the project of building a canal was attempted and completed in the early 1900s, with the canal opening in 1914.

Agreements – Who Provides What?



International Space Station Facts



Spacecraft Mass: ~862,000 lb
Velocity: 17,500 mph
Altitude: 220 miles above Earth
Habitable Volume: 13,696 cubic feet
Pressurized Volume: 32,333 cubic feet
Usual crew size: 6

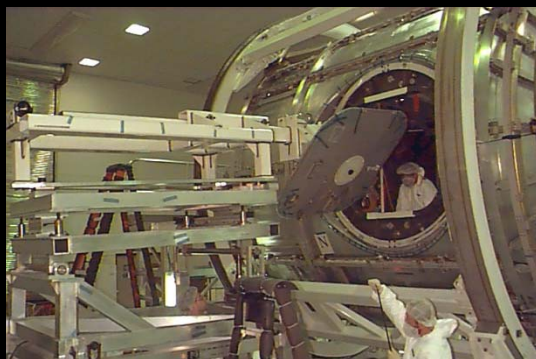
International Space Station Key Challenges

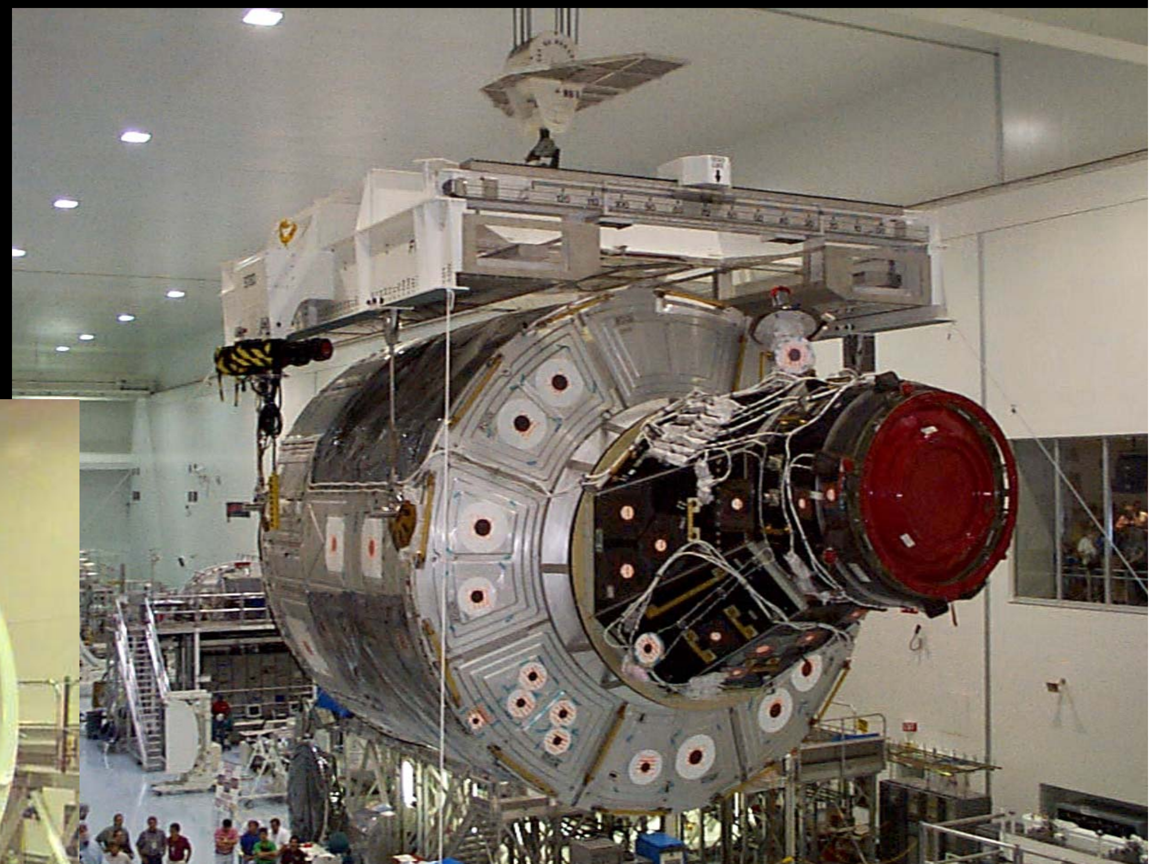
- Communication across languages, cultures, time zones
- Differences in technical approaches and understanding across Partners
- Hardware/software that would never see each other on the ground had to fit and function on-orbit
- Multi-generational Program (people and hardware)
- Change in orbital inclination from 28.5 (Freedom) to 51.6 degrees
- Declining industrial base in the United States
- Chaos in the Russian economy in the late 1990's
- Extensive EVA requirements
- Application of product based management methods in midstream
- No dedicated system level qualification test articles on U.S. side—"hardware poor"
- Compliance with U.S. Export Control Laws in an International program
- Limited availability of personnel with spaceflight hardware development experience

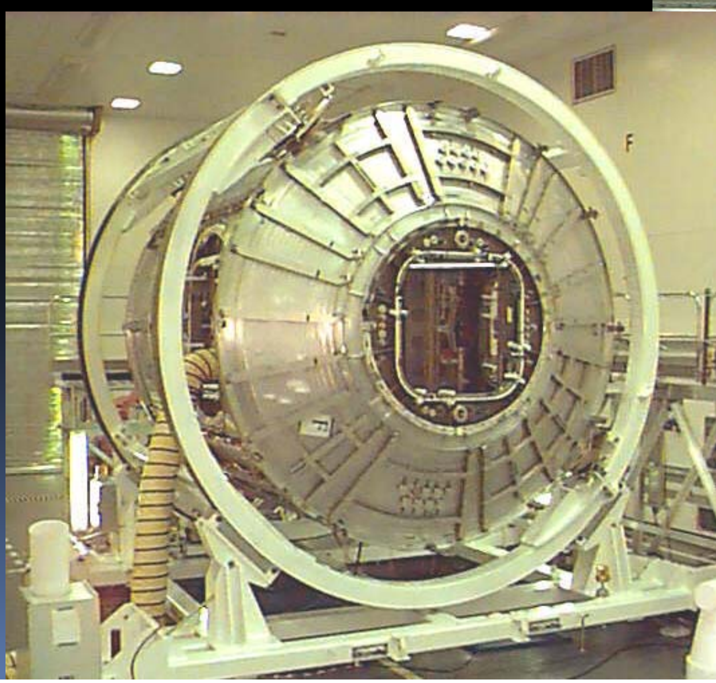
ISS Key Lessons

- Stable, technically astute leadership and good relationships are essential
- Assure critical processes have adequate pathfinders done ahead of need
- Integrated testing must be a priority
  - Deletion of dedicated system level test beds is a false economy
  - Cost of schedule delays in a large program will eat any savings quickly
  - Must have purpose built, high fidelity hardware /software integration laboratories
  - Multi-Element Integrated Testing was the most critical investment for the early success of ISS (even though it was added late)
- Overdependence on a single supplier can have dire consequences
- Investments in EVA tools, simulation, and training were well justified by the results achieved
- Unwavering dedication to testing and understanding /solving anomalies pays off in mission success—"it all has to work"
- Use caution in applying product based management structures as they can dilute checks and balances, particularly in specialized disciplines (e.g. stress)
- There is no substitute for experience in spaceflight hardware development
  - Space Stations are not airplanes!
- A combination of strategically employed mockups, fit checks, and optical imaging/virtual assembly techniques was essential to assure that on-orbit fit up would be successful

Node 1 “Unity”

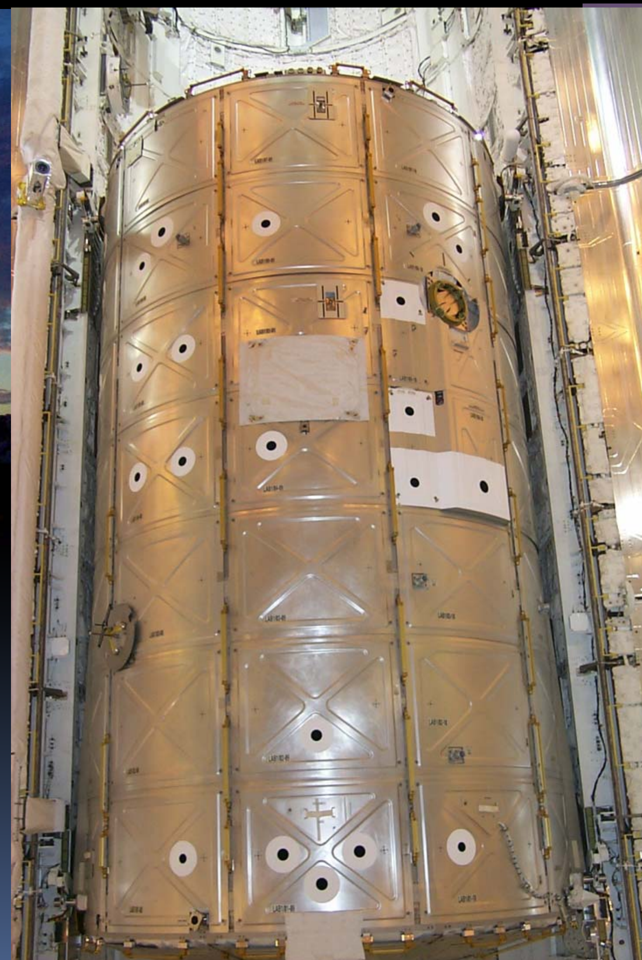






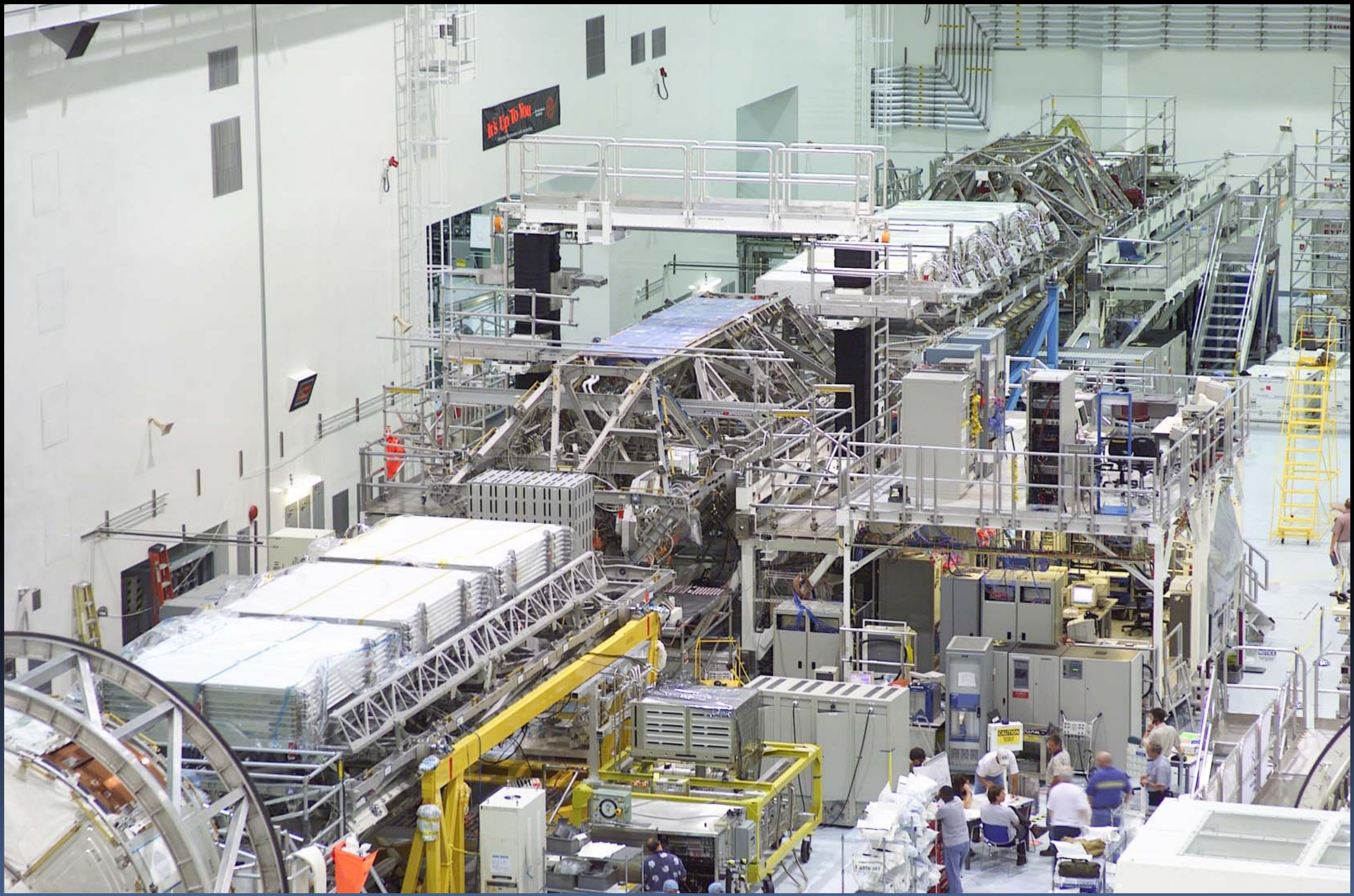
United States Laboratory “Destiny”



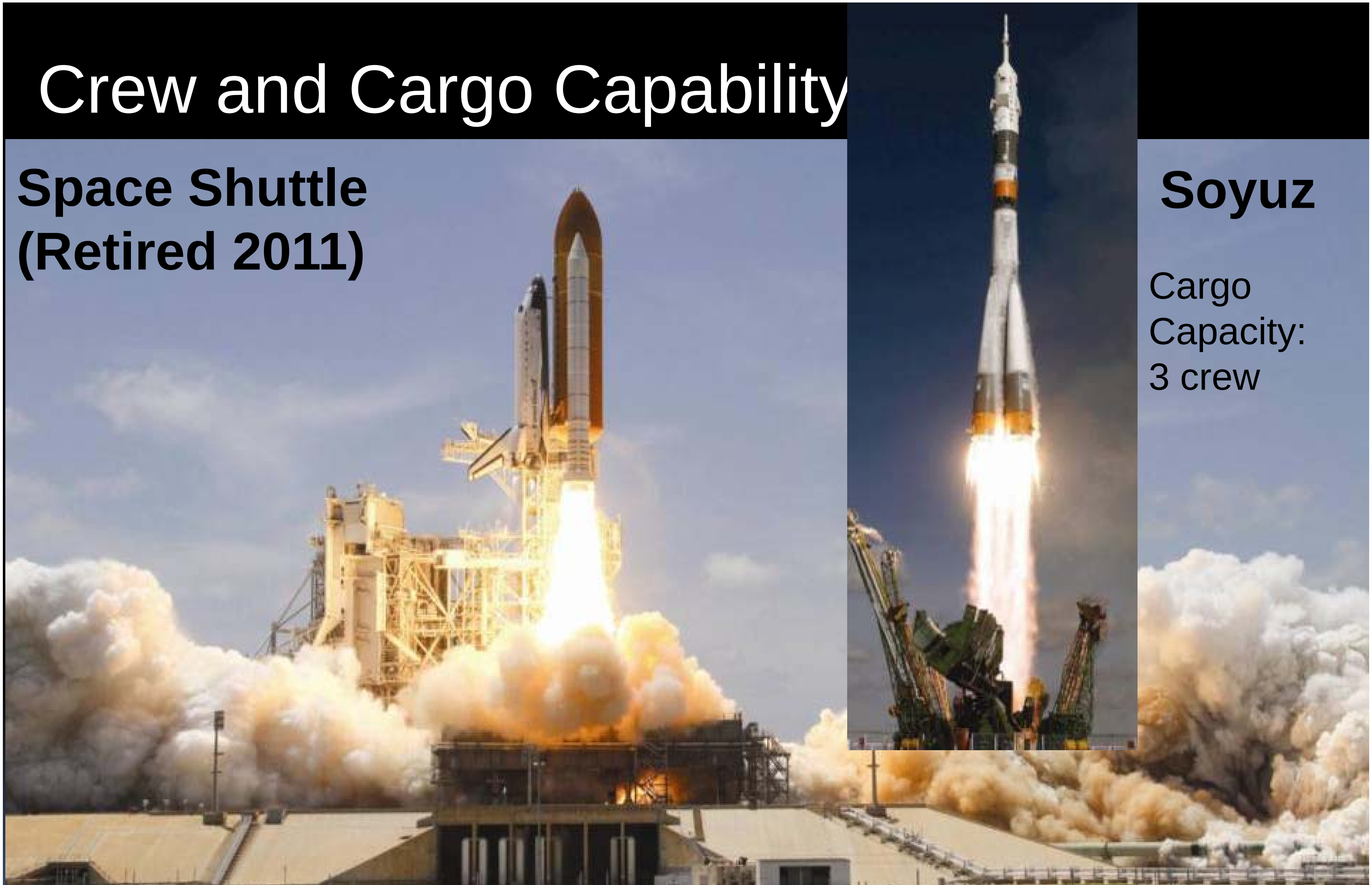




Multi-Element Integrated Testing at Kennedy Space Center



Crew and Cargo Capability



Space Shuttle (Retired 2011)

Soyuz

Cargo Capacity: 3 crew

Future U.S. crew capability being developed by Commercial Crew and Cargo Development (CCDEV) Program

Current and Future Cargo Capability

Proton
Progress



ROSCOSMOS

Ariane 5
ATV



esa

H-IIB
HTV



JAXA

Falcon 9
Dragon



SpaceX

Taurus II
Cygnus



Orbital

An International fleet of space vehicles that delivers propellant, supplies and replenishes science experiments

ISS Cargo Vehicles

Progress

Cargo Capacity
2,250 kg





ATV (ESA)

Cargo Capacity
5,500 kg



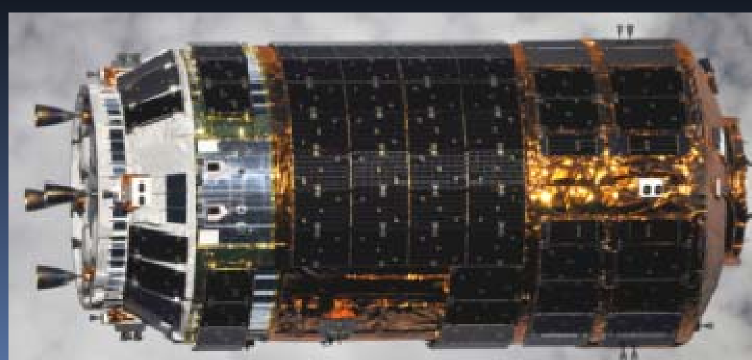
Cygnus (Orbital)

Cargo Capacity
2,000 kg



Dragon (SpaceX)

Cargo Capacity
3,100 kg ascent



HTV (JAXA)

Cargo Capacity
5,500 kg

Exercising in Space



CEVIS
Cycle Ergometer with
Vibration Isolation System

Russian Treadmill





COLBERT
Combined Operational
Load Bearing Exercise
Treadmill

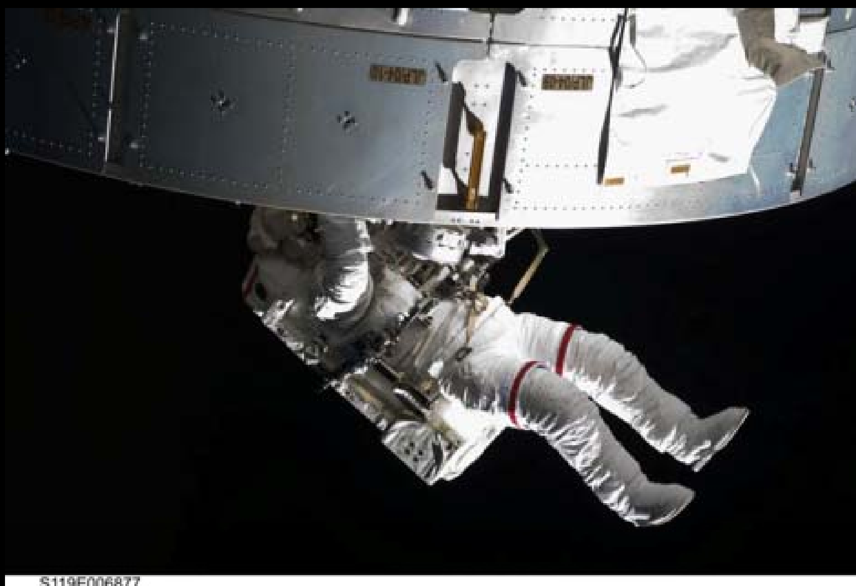


Russian
Cycle Ergometer

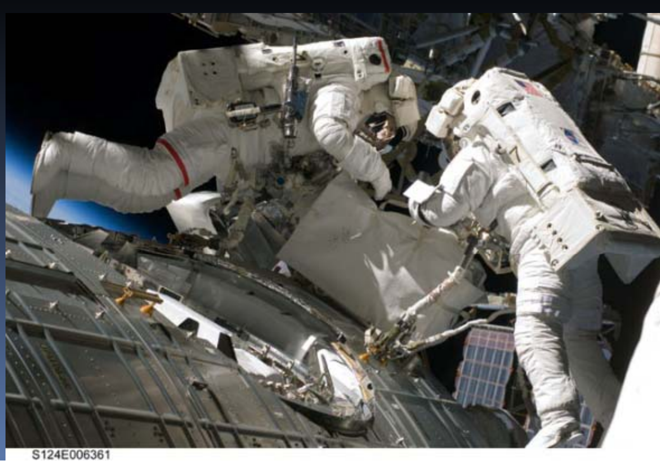


ARED
Advanced Resistance
Exercise Device

Working in Space (EVAs) -161 Total Spacewalks

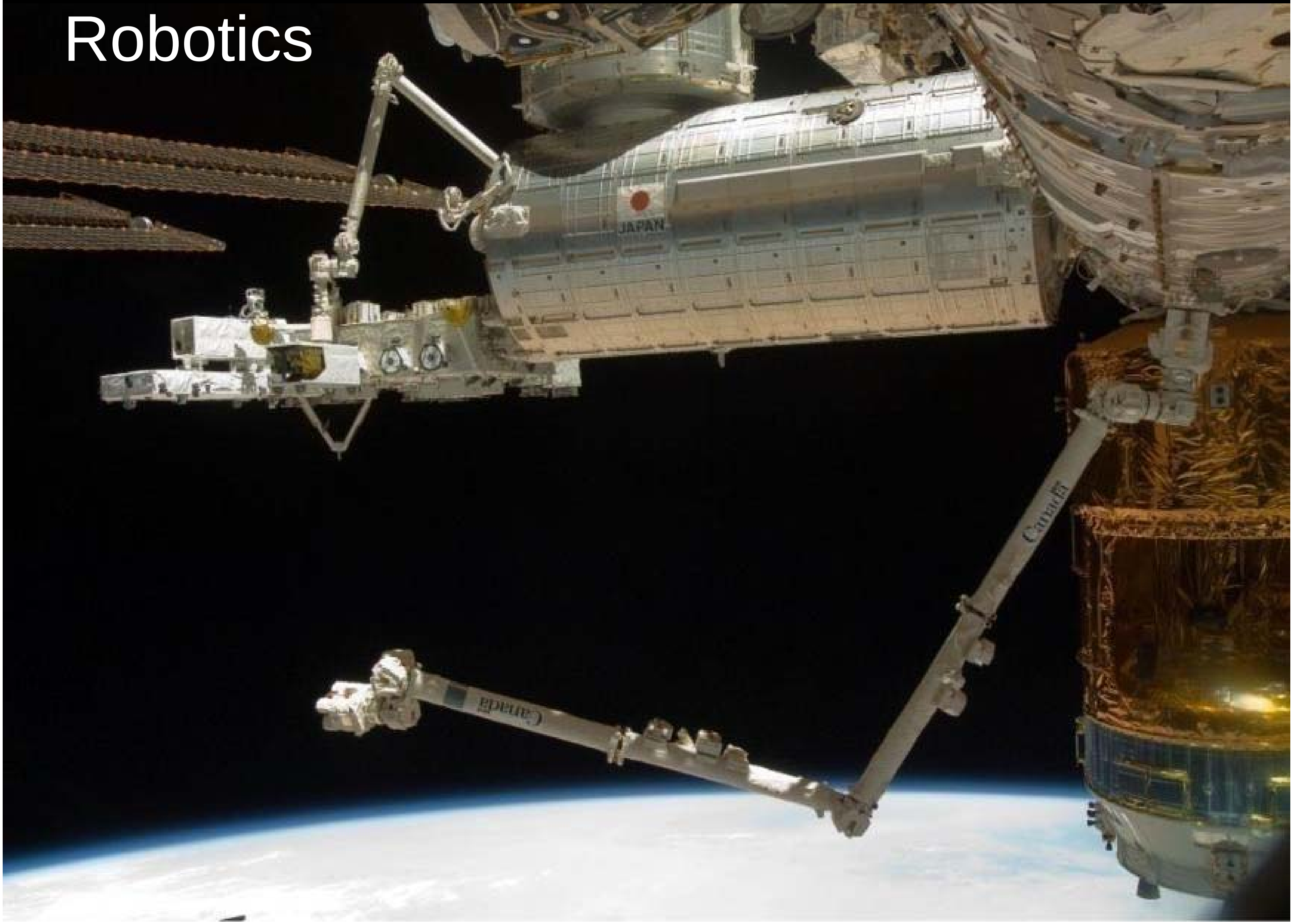




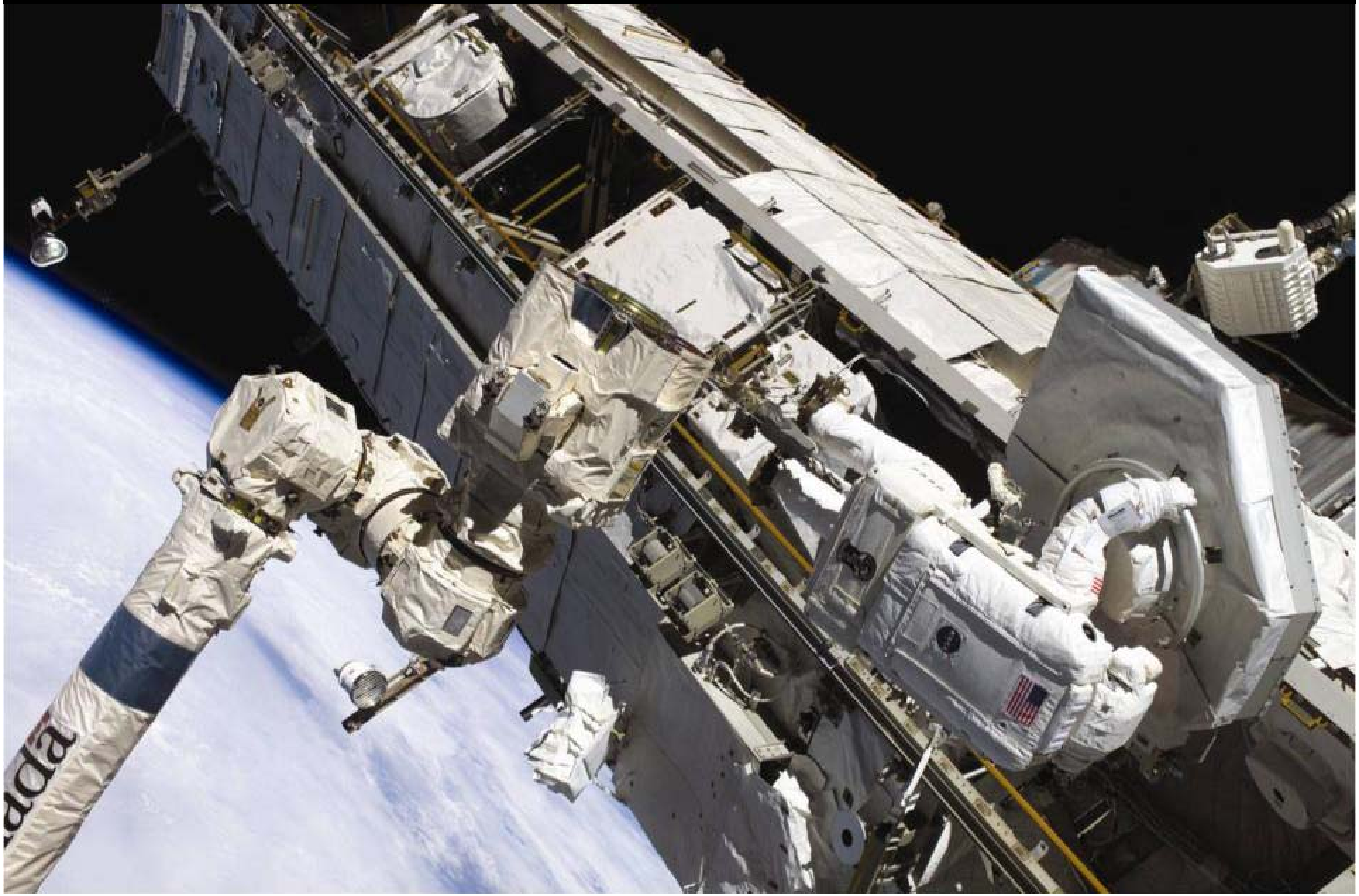




Robotics



Support Assembly and Maintenance



Robotics



Working in Space
International Space Station Unique Features

- Robust, continuous, sustainable microgravity platform
- Continuous human presence in space
- Access to the ultra high vacuum of space
- 30kw steady state power for payloads
- Unique altitude for observation and testing
- Payload to orbit and return capability

Why Microgravity Research?



A candle flame in Earth's gravity (left) and microgravity (right) showing the difference in the processes of combustion in microgravity

- Gravity is a constant force on Earth
- It cannot be completely controlled or removed in experiments
- It dominates and masks other forces in processes
- The ISS provides a laboratory environment to control this force

Internal Research Accommodations

Architecture based on Modular racks

Modularity = maintainable, reconfigurable, interchangeable between ESA, JAXA, NASA

34 Total Racks









Material Science Glove Box



Provides a safe environment for research with liquids, combustion, and hazardous materials

Being modified to support Biology and Bio-technology

Minus Eighty-degree Laboratory Freezer for ISS (MELFI)





Provides thermal conditioning at +4ºC, -26ºC and -80ºC for sample (blood, urine, tissue, etc) preservation
3 Units on-orbit

ExPRESS Sub Rack Payloads





<u>ABRS</u>

Advanced Biological Research System

Two growth chambers; each chamber is a closed system capable of independently controlling temperature, illumination, and atmospheric composition to grow a variety of biological organisms.

Biological Experiment Laboratory *(BioLab)*

Used to perform space biology experiments on micro-organisms, cells, tissue cultures, small plants, and small invertebrates.

It includes a incubator with microscope, spectrophotometer, and two centrifuges, glove box and two cooler/freezer units.





Human Research Facility *(HRF)*



HRF-1 Rack



HRF-2 Rack



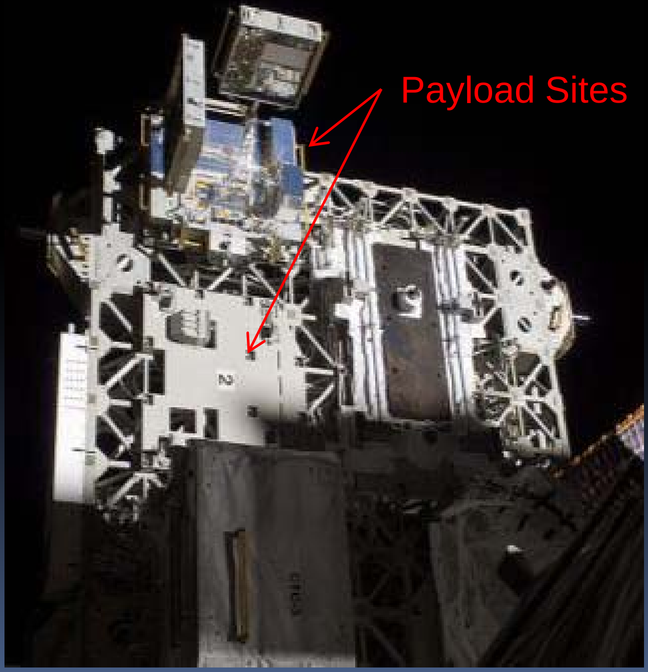
Ultrasound

2 Human Research Facility (HRF) Racks - Biomedical investigations, including ultrasound, body mass measurement, metabolic gas analysis, pulmonary monitoring, ambulatory blood pressure measurement, Holter monitor, and experiment unique hardware

External Research Accommodations

**22 External
Research Facilities
(including Alpha-Magnetic
Spectrometer)**

MISSE 7







Working in Space -Windows to the Earth

Service Module Window

40-cm diameter

NADIR view



Window Observation Research Facility

(WORF)



US Laboratory Window
50-cm diameter
Telescope-quality optical glass
NADIR view



WORF Rack

Facility to support visual and multispectral remote sensing using Lab Optical Window

Working in Space
(Earth Observations)





Crew Earth Observation

Targets of opportunity are uplinked each day to the crew based on that days orbital track



Human disasters

Gulf of Mexico Oil Spill, 4 May 2010, ISS023-E-32397


Crew Earth Observation
Geologic phenomena
Sarychev Peak, Kuril Islands, ISS020-E-9048, 12 June 2009

Working in Space (Earth Observations)



ISS023E015878

Working in Space (Earth Observations)



Working in Space (Earth Observations)



Crew Earth Observation
(CEO)



ISS026E020611

Land use, agriculture studies and urban growth

Summary

- 27 years after President Reagan's call, humankind has completed its first permanent collaborative Space outpost, continuously inhabited for over 10 years
- The International Space Station is providing the capability to do multi-faceted research that expands our knowledge of the universe, enhances life on Earth, and enables human Exploration beyond Earth orbit
- Even though the Space Shuttle has retired, the United States continues to have an active human spaceflight program with ISS as its centerpiece

ISS Sightings

http://www.jsc.nasa.gov/sightings/

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